REMOTE SENSING APPLICATIONS IN FORESTRY

MULTISTAGE, MULTISEASONAL AND MULTIBAND IMAGERY TO IDENTIFY AND QUALIFY NON-FOREST VEGETATION RESOURCES

by

Richard S. Driscoll
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Rocky Mountain Forest and Range Experiment Station
Forest Service, U. S. Department of Agriculture

Annual Progress Report — 30 September, 1970

A report of research performed under the auspices of the

Forestry Remote Sensing Laboratory,
School of Forestry and Conservation
University of California
Berkeley, California
A Coordination Task Carried Out in Cooperation with
The Forest Service, U. S. Department of Agriculture

For

EARTH RESOURCES SURVEY PROGRAM
OFFICE OF SPACE SCIENCES AND APPLICATIONS
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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ABSTRACT

This is the third annual progress report of a study to assess the merits of space and supporting aircraft photography for the interpretation and analyses of non-forest (shrubby and herbaceous) native vegetation. The research includes the development of a multiple sampling technique to assign quantitative area values of specific plant community types included within an assigned space photograph map unit. Also, investigations of aerial film type, scale, and season of photography for identification and quantity measures of shrubby and herbaceous vegetation have been conducted. Some work has been done to develop automated interpretation techniques with film image density measurement devices.

The aerial photoscales to use for subsampling space photographs for area of plant community types depends on the complexity of the vegetation within a space photo mapping unit. For a pinyon-juniper forest mapping unit near Roswell, New Mexico, included in Apollo exposure 3806, 1:20,000 scale photos were required to determine the areal extent of three specific plant community types verified by ground examination. Photoscales at 1:80,000 were of limited value because two of the community types could not be separated due to similar image characteristics. The best dot-grid system for estimating plant community area, considering cost and sampling error, is 36 dots per inch^2 using 50 percent of the subsampling units within a primary sampling unit. At least 2:1 ratio of secondary to primary sampling units is required to provide acceptable information about plant community area.

Identification of individual shrubs is significantly greater on large-scale color infrared aerial photos exposed in July as compared to normal color aerial photos. Considering all species, 82 percent of 456 test specimens were correctly identified on color infrared; 76 percent were correctly identified

on normal color. Mature plants of tall species are readily identified on photoscales up to 1:2,400. Photoscales of 1:800 or less are required for low-growing species in complex plant communities. Color infrared photos (1:600-1:800 scale) exposed in June provides the greatest amount of information for identifying herbaceous species.

Film image density, measured by microdensitometry, of different classes of standing crop on seeded rangeland are significantly different. Image density of grass stands representing 20 percent increments of crop year production was significantly less than the image density representing total production.

Optical-mechanical scanner data collected by the University of Michigan aircraft and the NASA RB57F in July 1970 have not yet been analyzed.

ACKNOWLEDGMENTS

This research is being performed under the Earth Resources Survey Program in Agriculture/Forestry under the sponsorship and financial assistance of the National Aeronautics and Space Administration, Contract No. R-09-038-002. This is the third annual progress report of a cooperative program with the Forest Service, U. S. Department of Agriculture. The research involves two Forest and Range Experiment Stations: the Rocky Mountain at Fort Collins, Colorado, and the Pacific Southwest at Berkeley, California. Salaries of all professional employees are being contributed by the Forest Service.

We are particularly grateful to Mr. Philip G. Hasell, Jr., IROL, University of Michigan for technical advice during the optical-mechanical scanner mission in July.

Special appreciation is extended to Drs. P. O. Curries, M. J. Morris and O. C. Wallmo of the Rocky Mountain Station who contributed their talents and resources in the conduct of this research.

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MULTISTAGE, MULTIBAND, AND SEQUENTIAL IMAGERY TO IDENTIFY AND QUANTIFY NON-FOREST VEGETATION RESOURCES

by

Richard S. Driscoll
Richard E. Francis

INTRODUCTION

Inventory and surveillance of native vegetation is an increasingly important facet of land use planning, development and management. It is especially important in light of expanding human populations with increased leisure time and affluence. For example, the population increase in Colorado according to preliminary estimates of the 1970 census amounted to approximately 25 percent. The major portion of this increase occurred along the Colorado Front Range, from Fort Collins to Pueblo. Other areas of the United States and the world are experiencing similar changes.

These occurrences are creating demands for living and recreation space. This space is available from two sources: (1) cropland and (2) noncropland which supports a variety of native vegetation. The latter category includes land area used for outdoor recreation, livestock grazing, timber production, food and cover for wildlife and is the principal source of domestic and commercial water supplies. These lands are hillier, rockier, drier and more remote than most cropland making it more complicated to unlock the interrelationships of land use demands including the impact of urbanization. What better way is there to provide instantaneous data synoptically to make and monitor decisions on land use planning, development and management, especially effects of human activity on native vegetation, than by remote sensing?

This is the third annual progress report detailing research undertaken since October, 1969. The first report (Driscoll and Reppert 1968)

summarized the importance of the problem regarding detection, identification, and measurement of herbaceous and shrubby vegetation; essentially an establishment report for continuing research. The second report (Driscoll 1969) detailed more potential applications of remote sensing to land use and management and provided preliminary findings on multiple sampling for plant community classification and quantification using Apollo 9 exposure 3806 (color infrared) of the Roswell, New Mexico area. Included also in this report were preliminary findings on shrub species identification using large-scale color (Anscochrome D-200) and color infrared (Ektachrome Infrared Aero, Type 8443) aerial photographs. These reports point out the needs for sequential and multiple-scale aircraft photography for support information related to space photography to secure facts about a specific parameter, e.g. the delineation of a plant community or identification of a specific plant species.

This report will summarize the main efforts during the past year and include: (1) refinement of sampling with Apollo 9 exposure 3806, (2) statistical results and inferences for shrub identification including effects of season and photoscale thresholds, (3) preliminary results of herbaceous species identification using large-scale Anscochrome D-200 and Ektachrome Infrared Aero Photographs, and (4) preliminary results of an experiment designed to measure herbaceous standing crop using aerial photographs and the microdensitometer.

We did get four flights (32 runs) on July 28 and 29 over the Manitou, Colorado test site (NASA Site 242) with the 17-channel multispectral scanner from IROL of the University of Michigan as part of Mission 19M. The NASA RB57F overflew the same test site on July 21 as part of Mission 139 for photography and thermal imagery. We do not have the imagery, playback tapes, or photographs at this time but will report the results as soon as possible.

THE STUDY AREAS

The same study areas reported in the September 1969, progress report were used again this year. These include: (1) Black Mesa on the Gunnison National Forest near Montrose, Colorado, (2) Manitou on the Pike National Forest near Colorado Springs, Colorado, (3) Kremmling near the town of Kremmling, Colorado, in north-central Colorado, (4) McCoy in the upper Colorado River drainage, and (5) Roswell in southeastern New Mexico, the area included in Apollo 9 frame 3806. Detailed descriptions of these areas, including vegetation, climate and soils, appeared in the two earlier reports.

Major effort for data acquisition this past field season was concentrated at the Manitou area. The reason for this is threefold: (1) The area is designated as one of our proposed study sites for ERTS-A experiments in cooperation with the Forestry Remote Sensing Project, Pacific Southwest Forest and Range Experiment Station, R. C. Heller, Project Leader. (2) The area has been selected as a proposed comprehensive study site for the newly formed Forest Service Mountain Grassland Ecosystem Project. (3) Current research in the area is multidisciplinary, designed to determine the effects and interrelations of native vegetation manipulation on timber, range and wildlife resources. Information trade-off among the Forest Service projects doing research at Manitou provides us with a significant amount of ground truth data for analyses of imagery that we would otherwise not be able to accumulate. Likewise, our remote sensing data assists them in analysis and interpretation of their on-the-ground data.

PROCEDURES

As inferred earlier, most of the effort during this reporting year was spent in interpretation and analysis of existing aerial and space photographs. We have attempted to develop photogrammetric techniques, both manual and

automated, to relate specific quantitative data to space-type photographs similar to those obtained during the Apollo 9 mission. Although not all information is directly related to the specific Apollo photo, the relationships become apparent as more detailed information is required about resources imaged in photographs from space.

A. MULTIPLE SAMPLING WITH SPACE PHOTOGRAPHS

Apollo 9 exposure 3806 (color infrared) of the Roswell, New Mexico area was used for this part of the research. This photo was taken 12 March 1969 and included an area of approximately 10,000 square miles. The original photoscale was approximately 1:2.8 million.

Detailed ground examination provided for mapping five generalized vegetation units using the space photograph. These included: (1) a Grama-Galleta Steppe, (2) a Creosote Bush-Tarbush Shrub unit, (3) a Grama-Tobosa Shrubsteppe, (4) a Mesquite-Shinnery Shrub unit, and (5) a Juniper-Pinyon Pygmy Forest. Due to the very small photographic scale and the complexity of the plant communities involved, it must be understood that a mapped unit on the space photo represents a group of plant community types, rarely an individual entity.

Five locations were selected for a more detailed sampling experiment to quantify the elements originally mapped. These locations were used as representative examples of the generalized vegetation types of the whole area (Figure 1). Brief descriptions of these locations are:

1. A juniper-pinyon pygmy forest with associated grassland and waveyleaf oak (*Quercus undulata* Torr.) communities.
2. A semidesert grassland, portions of which had been burned a week prior to the photographic orbit. Nearly pure stands of tobosa grass (*Hilaria jamesii*) and giant sacaton (*Sporobolus wrightii*) are common especially on bottom lands and alluvial flats subject

Figure 1 A 3X enlargement of Apollo 9 exposure 3806 (color infrared) of the Roswell, New Mexico area. Map unit 1, consisting of approximately 15,392 acres determined by planimeter, was used to develop the multiple sampling rationale subsequently discussed. Three plant communities within this unit were identified on the ground: (1) grasslands intermingled with but associated to the mapping unit, (2) a waveyleaf oak-juniper community, and (3) the pygmy forest community with near pure stands of juniper.

to flooding.

3. A shrub type, part of the creosote bush-tarbush unit, in which creosote bush (Larrea divaricata) was the most conspicuous species of the area.

4. A shrub type, part of the mesquite-shinnery unit. Honey mesquite (Prosopis juliflora var. glandulosa) was the most abundant species in the area.

5. A shrub type, part of the mesquite-shinnery unit, characterized by numerous sand blowouts. Shinnery oak (Quercus harvardii) was the most abundant species.

One four-mile strip was flown over each area by the Forest Service Aero Commander to secure 70mm color and color infrared aerial photographs for our sampling study. Photoscales were 1:80,000, 1:20,000 and 1:2,400 along the same flight line. This photography was flown three months after the Apollo 9 exposure was made to provide needed correlation of photo imagery with plant development to interpret the space photo.

Location 1, the juniper-pinyon pygmy forest, was selected to develop in more detail the sampling strategy reported herein. The color infrared photos were used because plant community and species discrimination are easier using this film type as compared to color film.

Ground examination and photo interpretation revealed three primary plant communities within this mapping unit. These were: (1) Grasslands intermingled with but associated to the mapping unit. The major grass species in this unit was galleta (Hilaria jamesii). Snakeweed (Gutierrezia sarothrae) was an abundant shrub. Occasionally juniper (Juniperus monosperma) occurred in this type. (2) The waveyleaf oak-juniper unit in which the oak occurred almost exclusively on sandy hummocks two to three feet above the surrounding terrain. Sand

dropseed (Sporobolus cryptandrus) occurred on the hummocks with the oak in addition to lesser amounts of three-awn (Aristida spp.) and grama (Bouteloua spp.). Juniper occurred between the hummocks. (3) The pygmy forest itself where juniper occurs almost exclusively. Reasons for separating these community types was based primarily on kind of associated soil. The grasslands were associated with silty clay soils, the oak areas with sandy soils and the juniper areas with shallow sandy cobbly soils. These community types as seen from the air are illustrated in Figure 2.

Based on our previous experience, it was evident we needed to improve sampling techniques to secure better data to quantify the space photo (Driscoll 1969). This is primarily related to determining the areal extent of the individual plant community types within the ecosystem set or mapping unit using a dot-grid technique.

Five dot-grid densities (16, 36, 64, 100 and 144 dots per inch^2) were used to determine the "best" grid pattern to estimate the area of each community type. "Best" is defined as that grid system which yields an area estimate with the least standard deviation consistent with a minimum cost in relation to sampling intensity. The multiple sampling design used was basically a subsampling procedure in which larger scale photographs were used successively to sample the next smallest scale photographs.

Three photoscales were used. The Apollo scale, increased to 1:750,000, was used as base data from which the area of the experimental location was determined to be 15,392 acres by planimeter measure.

Complete stereo coverage along the flight strip was available for both 1:80,000 and 1:20,000 scale photographs. For the 1:80,000 scale, three frames, each of separate areas within the site, were used as primary sampling units and represented 35 percent of the total area. The 1:20,000 scale photos provided four frames to use as primary sample units and represented approximately 18

Figure 2 An aerial view (1:20,000, 2X enlargement) of the three primary plant communities represented in the juniper-pinyon pygmy forest mapping unit: (A) Grasslands with galleta grass, snakeweed and an occasional juniper. (B) The pygmy forest with a near exclusive stand of juniper. These units could not be detected or identified on either enhanced or degraded imagery from the space photo. (C) A waveyleaf oak juniper unit with dune-sand stabilized by waveyleaf oak, sand dropseed and lesser amounts of three-awn and gramma.

percent of the area included in the 1:80,000 scale photos. Secondary or subsample units were defined as squares of four dots each, independent of grid density.

Three subsampling intensities were used in conjunction with the various dot-grid densities. These were 40, 50 and 60 percent of all possible subsample units per primary sample unit. Our previous experience indicated that the 50 percent subsampling intensity used may or may not provide acceptable information.

Analysis of variance was used to calculate sample variances assuming the actual population follows a multinomial distribution. Such an assumption is valid, that the normal distribution approximates a multinomial distribution provided sample size is greater than 20 (Li 1964).

Variance within primary units (s_w^2) and variance between primary units (s_b^2) were used to calculate the standard deviation ($s_{\bar{y}}$) of the sample mean according to the following:

$$s_{\bar{\bar{y}}} = \sqrt{\frac{1}{mn}\left[s_b^2\left(\frac{N-n}{N}\right) + s_w^2\left(\frac{M-m}{M}\right)\left(\frac{n}{N}\right)\right]}$$

where:

N = total number of primary units

M = total number of subsamples in the primary unit

$\left(\frac{N-n}{N}\right)$ and $\left(\frac{M-m}{M}\right)\left(\frac{n}{N}\right)$ are the finite population correction terms (Freese 1962)

Based on results of these calculations to determine which was the "best" grid density considering subsample proportion, optimum size sample units were determined according to the following:

$$(1)\quad m_{opt} = \sqrt{\left(\frac{\sigma_{II}^2}{\sigma_I^2}\right)\left(\frac{C_p}{C_s}\right)} \qquad (2)\quad n_{opt} = \frac{\left(\sigma_I^2 + \frac{\sigma_{II}^2}{m_{opt}}\right)}{D^2 + \frac{1}{N}\left(\sigma_I^2 + \frac{\sigma_{II}^2}{M}\right)}$$

where:

m_{opt} = optimum number of subsamples

n_{opt} = optimum number of primary units

$\sigma_{II}^2 = s_w^2$ (variance within primary units)

$\sigma_I^2 = \dfrac{s_b^2 - s_w^2}{m}$

$\dfrac{C_p}{C_s}$ = cost ratio between primary and secondary units: in this case 4:1

N = total number of primaries in the population

M = total number of secondaries per primary in the preliminary sample

D = a preselected standard error

B. SPECIES IDENTIFICATION

Additional aerial photography during the 1969 and 1970 seasons filled data gaps needed for our species identification work. This involves both season and scale of photography to determine when during the season at what photoscale threshold specific shrubby and herbaceous species can be identified most accurately.

Ground and aerial photo procedures were described in detailed earlier reports (Driscoll and Reppert 1968, Francis 1970). Plant species were marked and identified on the ground for positive identification in the aerial photographs. In addition, ground photographs of the test species were secured at each photo mission to provide additional reference material.

Film types used included Ektachrome Infrared Aero and Anscochrome D-200 properly filtered, to secure the various scales at the seasonal times listed in

Table 1. Location, season and scale of 70mm aerial photography of the Colorado test locations.

Location	Spring (6/1-15)	Early Summer (7/1-15)	Late Summer (8/1-15)	Early Fall (10/1)
Black Mesa		1:600 1:2,400 1:4,800	1:600 1:2,400 1:4,800	1:600 1:2,400 1:4,800
Manitou	1:600 1:2,400 1:20,000 1:105,000 1:140,000	1:600 1:2,400	1:600 1:2,400 1:4,800 1:9,600 1:20,000 1:80,000 1:140,000	1:600 1:2,400 1:140,000
Kremmling	1:600 1:2,400 1:4,800 1:10,000	1:600 1:2,400 1:4,800	1:600 1:2,400 1:4,800 1:10,000	
McCoy	1:1,200 1:2,400	1:1,200 1:2,400	1:1,200 1:2,400	

Table 1. All photography was flown by the Forest Service Aero Commander. All film was processed at the Forest Service Remote Sensing Project Laboratory, Berkeley, California.

Two approaches were used to gain information about identification of individual plant species with the aerial photographs. These were the development of selective and elimination photo interpretation keys (Simontacchi, Choate, and Berstein 1955). The selective key is so arranged that the photo interpreter simply selects the example corresponding to the image he is trying to identify. The elimination key is so arranged that the photo interpreter follows a prescribed step-by-step process leading to the elimination of all items except the one he is trying to identify.

An elimination key, basically dichotomous, was used for shrub species. The purpose of developing these keys was to learn what can be identified using large scale photographs in preparation for research on photogrammetric techniques to use with shrubby and herbaceous species. Seven major image characters were identified to be useful: plant size, image shadow, crown margin, crown shape, foliage pattern, image texture, and color. Various character states of each were also defined.

Selective keys were developed for herbaceous species. The image characteristics used were pattern, shape, shadow, relative size, texture and color. Definition of these are:

1. Pattern: the appearance of the image relative to the configuration or general appearance of the foliage in the plant, such as clumpy or continuous.
2. Shape: the relative geometric design of the plant such as circular or oblong.
3. Shadow: simply distinct, indistinct or absent.
4. Relative size: this refers primarily to the apparent height of

the species in relation to associated vegetation.

5. Texture: the apparent continuity of the foliage image dependent on leaf size, arrangement, branching and density with the individual plant.

6. Color: designated numerically and as a descriptive adjective according to National Bureau of Standards ISCC-NBS system of color designations.

These characteristics were scrutinized closely as each set of 10 replicates of plant species marked were examined using stereo photo-pairs. The resultant photo interpretation key was a detailed narrative description of each species including the character state ranges for each characteristic as it matched the imaged plant species.

For the shrub identification part of this work, statistical analyses have been completed. Results of data from four image analysts using the two film types for eleven species were analyzed using a factorial design. Analyses are not yet completed for the herbaceous species photo interpretation tests.

C. REMOTE MEASURES OF HERBACEOUS STANDING CROP

An ultimate analysis of aerial or space photographs would include a determination of herbaceous standing crop in specified plant communities. This could be considered an end product for some management decisions and would be extremely useful for evaluating and monitoring changes in energy balances of the vegetational component of ecosystems. Significant savings could be expected if ground sampling could be supplemented with photogrammetry to estimate production without sacrificing accuracy.

An experiment was initiated during the 1969 field season to determine if classes of herbaceous standing crop could be related to aerial photo-image characteristics either by manual interpretation or through use of a scanning

microdensitometer. The study area was located in seeded big bluegrass (Poa ampla) pastures at the Manitou test site.

Six levels of standing crop were simulated on 3 x 3 meter square plots by cutting to equal herbage height increments which ranged from 0 to 100 percent herbage removal. These increments were used to represent various levels of standing crop production as might be expected under varying yearly climatic conditions. They may also be viewed as representing levels of herbage utilization within the time frame of the current crop year. These treatments were replicated four times. Herbage remaining on each plot was estimated by double sampling with a heterodyne meter, an electronic device which senses mass within an array of probes as a relation of electrical energy storage of that mass (Neal and Neal 1965).

Aerial photographs were flown at two scales - 1:563 and 1:3,855 - at the peak of the growing season in mid-August. This was done with the Forest Service Aero Commander using two 70mm Maurer cameras, one loaded with Anscochrome D-200 and one with Type 8443 color infrared. All ground measurements were made within a week of the photo mission.

Interpretation of both film types indicated that color infrared would provide more discriminatory evidence of differences among standing crop levels than color film. Therefore, the color infrared photos were used in conjunction with the GAF 650 microdensitometer to provide estimates of image density differences among the various treatments. The machine was programmed to scan with an effective circular aperture of $416\mu^2$ using a green filter. Preliminary tests showed that the green filter provided greater scan-line frequency and amplitude differences among treatments than other filters.

Since the study area was seeded pastures, all scan lines were run perpendicular to the drill rows. Thus, possible scan lines including either only vegetation or only bare spaces between drill rows were avoided. For the 1:563

scale photos, nine random starts were selected for each imaged plot treatment; five random starts per plot were selected for the 1:3,855 scale photos.

The microdensitometer we used provided a readout in the form of a strip chart record. To digitize this for analyses, we systematically picked points off the strip charts to provide information on mean transect density, each transect mean comprising an observation. This data was then subjected to analysis of variance and testing for significance within and among treatment effects using the Duncan multiple range procedure (Duncan 1955).

RESULTS

A. MULTIPLE SAMPLING WITH SPACE PHOTOGRAPHS

As previously mentioned, aerial photographs at three different scales (1:2,400, 1:20,000 and 1:80,000) were obtained as sampling photography for the AS-9 data base. For the current problem, we did not use the 1:2,400 scale since this was secured primarily for shrub species identification and quantification. How this might be done specific to the study area was explained in our 1969 annual report. Also shrub species identification will be detailed more explicitly in the next section of this report.

The 1:80,000 scale color infrared photos could not be used to estimate the area of the three community types regardless of grid density size. The image differences between the juniper unit and the waveyleaf oak-juniper unit were so subtle, and commission errors in interpretation were so great, based on ground truth, that the data was not acceptable (Figure 3). Differences between the grassland unit and the others were also so marginal in some cases that the data quantifying the extent of these units might be questionable. This was caused by the gradual gradations of image characteristics at the edges of the community types. The interpretation problems occurred primarily in deciding where the boundaries between the three types occurred. Therefore, the 1:80,000

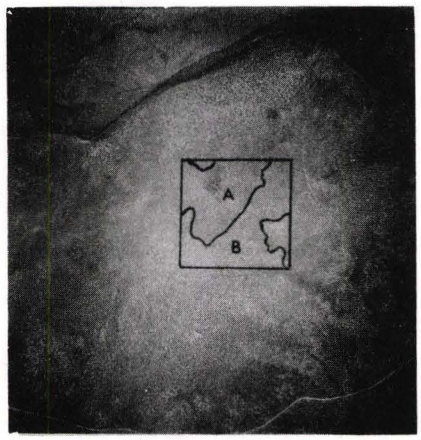


Figure 3. Image difference between the juniper community (B) and the grassland community (A) were sufficiently discriminate that they were easily separated in 1:80,000 scale photographs. However, the waveyleaf oak-juniper unit was difficult to discretely separate from either of these. Compare this to Figure 4, the area outlined here at 1:20,000 scale.

scale photographs might not be useful for community demarcation of the magnitude of classification verified by on-the-ground examination.

However, if an investigator is interested only in vegetation class discrimination at one level of refinement above the class order possible using space-type photographs alone - considering similarities of this particular study area and the detail of classification we used - 1:80,000 or smaller scale photos might be acceptable. In this case, areas where juniper occurs or does not occur could be separated and plotted accurately on photoscales of 1:80,000 and possibly smaller. The presence of juniper provided a major contrasting image difference used to separate these communities from others without juniper. However, more than two community types should be identifiable at this scale if the dot-grid sampling technique is used. When only two elements are under investigation within a specified area, the areal extent of one is fixed in relation to the other. If only two elements are involved, the calculated statistical variance is the same for both elements and does not provide a valid estimate of error.

The larger scale (1:20,000) color infrared sampling photographs provided the primary sampling data for this problem. The three ecosystem types previously defined could be easily interpreted with confidence (Figure 4). In these photos, the mottled, somewhat stippled image characteristic of the oak-juniper community was easily differentiated from both the grassland and the juniper communities.

Preliminary sampling using the five grid densities showed that the information gain using the 100 and 144 dots per inch^2 grids was insignificant in relation to reductions in the standard deviation influenced by costs to do the sampling. For example, a 10 percent reduction in the standard deviation using the 100 dots per inch^2 grid required 40 percent more sampling time than when using the 64 dots per inch^2 grid. The relationship doubled when comparing the 144 dots per inch^2 grid with the 64 dots per inch^2 grid for a 10

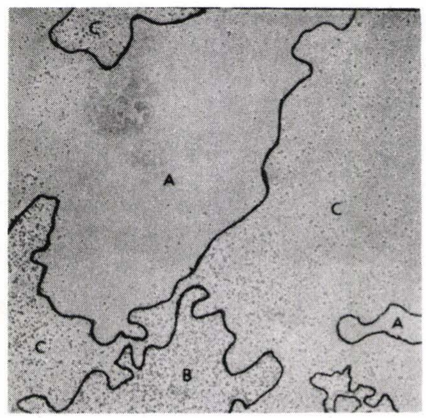


Figure 4. The three plant community types included in the photography for this problem were easily separated and area determinations made on 1:20,000 scale photographs: (A) grasslands, (B) juniper, (C) waveyleaf oak-juniper.

percent reduction in the standard deviation.

The "best" grid system to estimate the area of each community type comparing the other three grid densities was ascertained to be the 36 dots per inch^2 grid using 50 percent of the subsampling units (Table 2). This conclusion is supported by being least expensive for obtaining acceptable results, considering the sampling time element in relation to a unit reduction in the standard deviation. On the average increasing sample size to the 64 dot grid doubled sampling time for an insignificant decrease in standard deviation. The decrease in standard deviation comparing the 16 and 36 dot grids was sufficient to warrant using the latter grid density in relation to sampling time required for each grid size.

From these data, the optimum sample size for both primary and secondary units was determined on the basis of a preselected 10 percent standard error using formulas (1) and (2). The number of primary units (^{n}opt) and the number of secondary units or subsamples per primary unit (^{m}opt) were found to be as follows:

(1) Oak-juniper community $^{n}opt = 3$ $^{m}opt = 18$

(2) Grassland community $^{n}opt = 6$ $^{m}opt = 12$

(3) Juniper community $^{n}opt = 6$ $^{m}opt = 13$

Computation of optimum sample size is based on standard error estimates of the preliminary sample and not on estimates of the standard deviation. Since the standard error is dependent on subsample area, it would be suspected that the largest subsample area would yield the smallest standard error estimate. Our data confirms this suspicion.

These data provide us, or any investigator, foundation information about how earth resources imagery from earth orbiting satellites might be quantified by sampling with aircraft photography. It must be recognized that only three photoscales were used for support sampling photographs to quantify the AS-9

Table 2. Comparisons of standard deviations using various dot-grid densities in relation to sampling time and intensity: Photoscale - 1:20,000

Subsamples Used	Grid Size	Time	Waveyleaf Oak Area	Waveyleaf Oak $s_{\bar{y}}$	Grassland Area	Grassland $s_{\bar{y}}$	Juniper Area	Juniper $s_{\bar{y}}$
Percent	Dots/in.^{2}	Min.	Percent	Acres	Percent	Acres	Percent	Acres
60	16	50	35	0.615	31	0.612	34	0.551
	36	60	36	0.592	36	0.578	28	0.489
	64	120	37	0.410	40	0.435	23	0.334
50	16	15	44	0.626	28	0.728	28	0.784
	36	40	39	0.565	34	0.570	27	0.461
	64	90	38	0.463	33	0.458	29	0.423
40	16	15	43	0.904	37	1.470	20	0.713
	36	25	41	0.756	31	0.689	28	0.635
	64	55	39	0.555	32	0.481	29	0.499

color infrared photograph of the Roswell, New Mexico area. It must also be recognized that as interpretation and sampling is extended to other regions with different kinds of vegetation, different sampling procedures would warrant investigation. From this New Mexico data, it is apparent that at least a 2:1 ratio of secondary to primary sampling units would be required to get acceptable information about plant community area using 1:20,000 scale photographs. Acceptable is defined as approximating a 10 percent standard error of estimate. This ratio varied among plant community types included in this experiment. Similar research would be needed to determine the optimum sampling ratios for other areas. We plan to determine what these relationships are using the high flight photography that was flown over the Manitou test site this past season.

B. SPECIES IDENTIFICATION

1. Shrub Species

Statistical analyses using a factorial design were completed for a photo interpretation test designed to compare color and color infrared aerial photographs for shrub species identification. Photoscales ranged from 1:600 to 1:10,000 obtained four times during the summer growing season. Film-filter combinations, photoscales, and the areas over which the photography was obtained was detailed in earlier reports and the PROCEDURES section of this report.

Image characteristics were defined for 11 shrubs. These characters and character states were arranged into a dichotomous elimination key which also included stereograms of the items under test. Descriptions of the image characters and character states together with the photo interpretation key for both film types are included in Appendix II of this report.

Four interpreters with varying degrees of photo interpretation experience and knowledge of the area included in the photographs completed the test.

These included:

1. An experienced interpreter familiar with the areas photographed and the associated vegetation.
2. An experienced interpreter unfamiliar with the areas but knowledgable about the vegetation.
3. A minimum experienced interpreter unfamiliar with the areas but generally knowledgable about the native vegetation.
4. An inexperienced interpreter unfamiliar with the area or the native vegetation.

At least 10 replicates were selected for nine of the species; more than six for the other two species. All test specimens were selected so ground physiographic features would not help the interpreter in identification. Early July aerial photos were selected. Detailed interpretation of all photos at all photographic dates revealed that the shrub species, as a whole, under test discriminated best at this time. This is based on the inference that if an investigator, because of budgetary or other constraints, had to limit efforts to a single time for data gathering, the early July time would provide the most useful information, all species considered.

Results of the photo interpretation test were as follows:

1. Identification of individual shrubs was significantly higher (P=.01) using color infrared positive transparencies regardless of interpreter experience or shrub species.
2. There was a significant difference (P=.01) among interpreters for identifying the species depending on photo interpretation experience and knowledge of the area imaged in the photos.
3. Identification of some species was significantly greater (P=.01) regardless of film type or interpreter, depending on plant size.

In general, 82 percent of the total 456 test specimens were correctly

identified using the color infrared photos; 76 percent were correctly identified using color (Table 3). Eight of the 11 species were identified at acceptable levels of accuracy (> 80 percent) using the color infrared; two of them identified 100 percent by all interpreters. Six species were identified correctly more than 80 percent of the time using color photos and none of them identified 100 percent correctly by all interpreters.

Greatest differences in species identification between film types were for bitterbrush, snowberry and mountain mahogany. Bitterbrush and snowberry had very similar colors both on the ground and in the color aerial photos. Consequently commission errors were high for these species. Greater color contrasts between the images of these two species in the color infrared photos provided for improved identification (Figure 5).

Mountain mahogany was frequently confused with small pinyon pine in the color photographs, especially when the apparent morphological characters as viewed in the film were similar. In the color infrared photos, color differences between the two species were sufficiently contrasting that commission errors for identification of mountain mahogany were very unlikely, at least on the basis of this research (Figure 6).

Snowberry and the two species of rabbitbrush were difficult to identify in either film type regardless of photoscales used (Figures 5 and 7). Image character differences among these species were apparently so similar that only the most astute interpreter could provide useable data. The most experienced interpreter identified these three species in the color infrared photos correctly 90, 92 and 92 percent respectively.

Differences among interpreters were linearly related to interpretation experience and knowledge of the area. The analyst with the most interpretation experience and knowledge of the area scored highest on the photo interpretation test. The least experienced analyst with least knowledge of the area

Table 3. Percent correct shrub identification by species and film type - all interpreters

Plant Species	EIR[1]	D-200[2]
Alkali Sagebrush (*Artemisia longiloba*)	100	98
Big Sagebrush (*A. tridentata*)	90	93
Mountain Mahogany (*Cercocarpus montanus*)	100	92
Parry Rabbitbrush (*Chrysothamnus parryi*)	60	54
Green Rabbitbrush (*C. viscidiflorus*)	56	50
Broom Snakeweed (*Gutierrezia sarothrae*)	93	88
One-seed Juniper (*Juniperus scopulorum*)	96	94
Pinyon Pine (*Pinus edulis*)	92	90
Bitterbrush (*Purshia tridentata*)	80	50
Cinquefoil (*Potentilla fruticosa*)	83	79
Snowberry (*Symphoricarpos* spp.)	65	53
Mean	82	76

[1] Ektachrome Infrared Aero (Type 8443)

[2] Anscochrome D-200 (Type 7230)

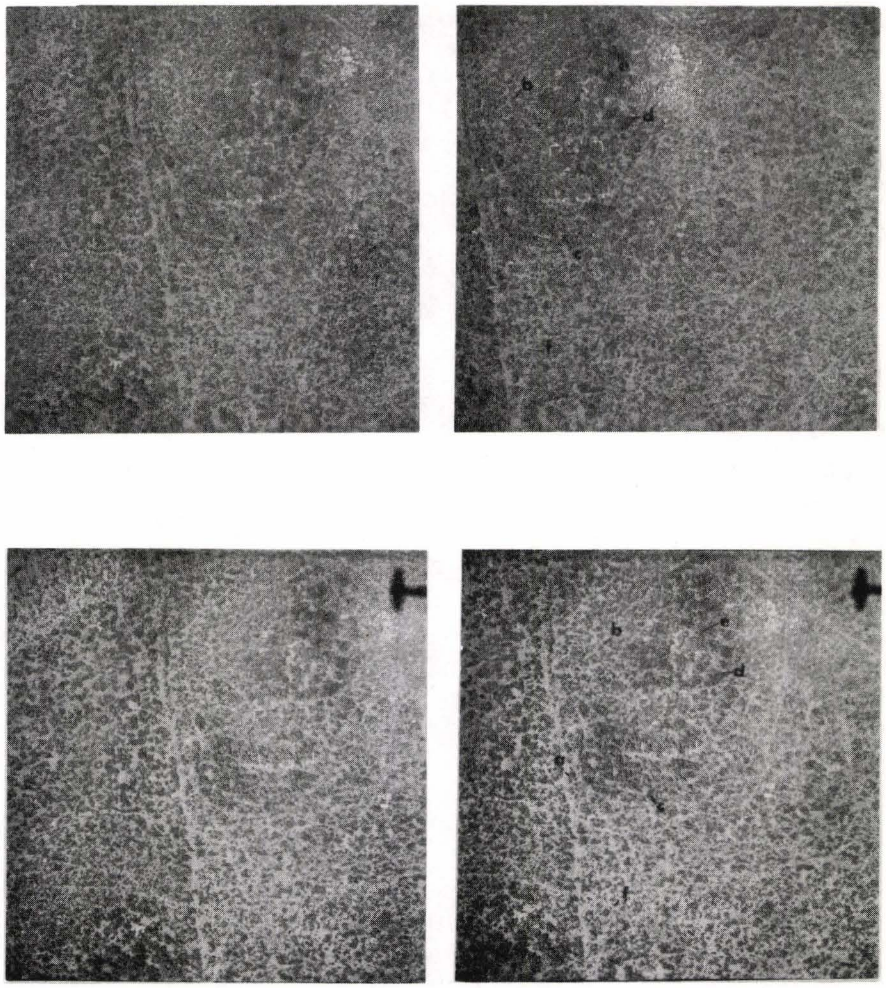


Figure 5 Top - Anscochrome D-200; Bottom - Ektachrome Infrared; both pairs at a scale of 1:800. Commission errors in identification of snowberry (d) and bitterbrush (e) were high in the color photos. Identification of the two species was improved using the color infrared. Other species indicated are: (a) big sagebrush, (b) alkali sagebrush, (c) green rabbitbrush, and (f) broom snakeweed. A 3-D effect can be achieved by viewing these photo pairs with a stereoscope. These stereo pairs form a part of the photo interpretation keys in Appendix II.

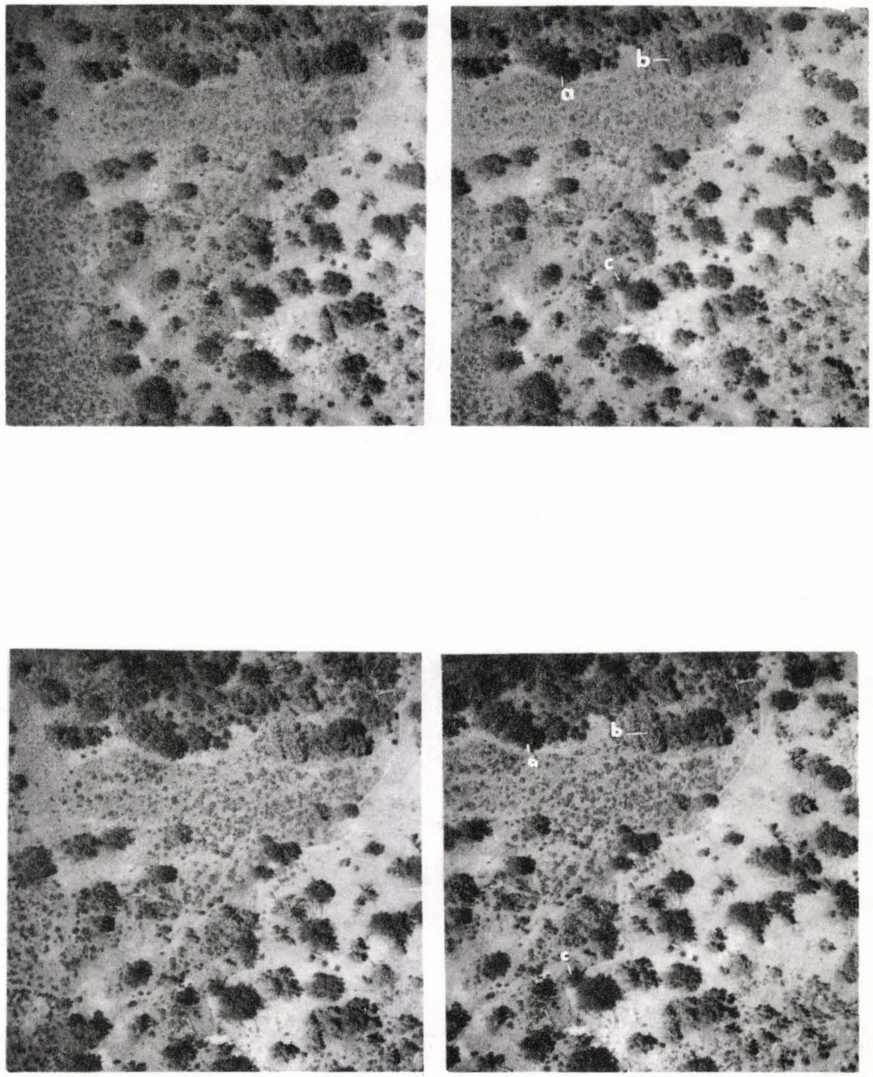


Figure 6 Stereo pairs in color (top) and color infrared (bottom) of mountain mahogany (c) at a scale of 1:1500. Color differences between this species and all others were sufficiently contrasting in the color infrared to provide 100 percent correct identification. Some commission errors occurred between this species and small pinyon pine in the color photos, although not of sufficient magnitude to warrant complete rejection of color photos for identifying the species. Other plant species indicated are (a) pinyon pine and (b) juniper. A 3-D effect can be achieved by viewing these photos with a stereoscope. These pairs form a part of the keys in Appendix II.

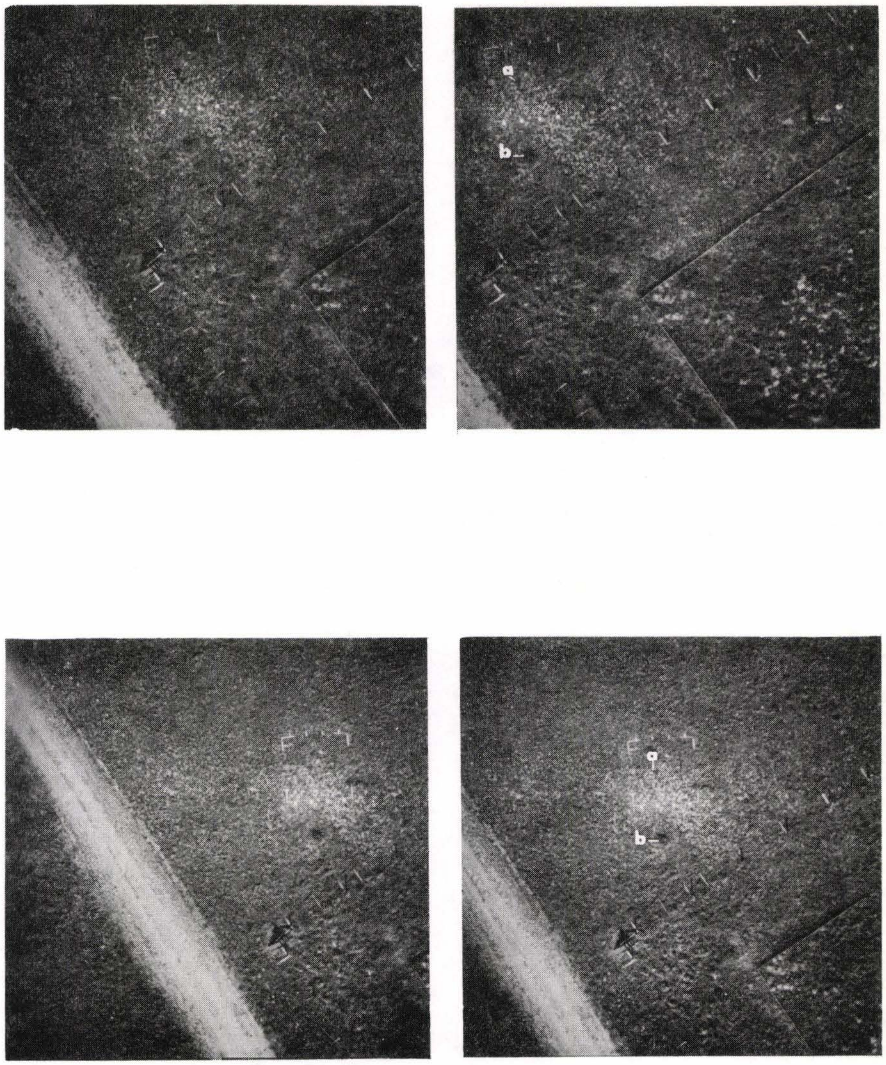


Figure 7 Rabbitbrush (a) is difficult to identify in either color (top) or color infrared (bottom) photographs even at photoscales of 1:600. Unless an interpreter knew that rabbitbrush was the only shrub species occurring in the area imaged in the above photos, commission errors were high, especially among the two species of rabbitbrush and snowberry. The other species indicated above is cinquefoil (b). See Figure 5 (d) snowberry and (c) rabbitbrush. A 3-D effect can be achieved by viewing these photos with a stereoscope. These stereo pairs form a part of the photo interpretation keys in Appendix II.

or the species scored lowest.

Detailed interpretation of the multiseasonal and multiscale photography for this research show that photoscales smaller than 1:2,400 had limited value for shrub identification by manual interpretation. Mature plants of relatively tall species, such as mountain mahogany and big sagebrush, were readily identified with photoscales to this magnitude provided crown margins did not overlap and there was a relatively sharp contrast between the species and background. Larger scale photos (1:800 or less) are required for photo identification of relatively low-growing shrubs, especially when associated vegetation is dense (crown margins touching or nearly so). Species with conspicuous flowers, such as cinquefoil, were identified equally well in late spring during blooming as well as late in the summer when integrated foliage characters differentiate the species from other associated vegetation. In complex shrub stands where plant crowns intermingle, identification of individual shrub species deteriorates rapidly at photoscales smaller than 1:950. Identification of some shrubs such as species of sagebrush which maintain contrasting differences from associated vegetation throughout the growing season, especially actual color, can be identified equally well at any time during the growing season.

2. Herbaceous Species

Interpretation tests completed thus far using the descriptive keys (Appendix III) were done by one experienced interpreter who is very familiar with the vegetation at Manitou (Table 4). A 4X lens stereoscope, stereo transparencies with comparative descriptions, phenology notes, and color chips were used with the 1:600 scale photos (Figure 8). The interpreter also applied confidence ratings (positive, some doubt, uncertain, guess) to his answers. Statistical analyses have not yet been applied to these data.

The results of all tests indicate that the June photographs provided the

Table 4. PI test summary...% correct identification by film type for three flight dates...Manitou (one interpreter)

Species or Item	D-200[1] 6/1/68	D-200[1] 7/3/68	D-200[1] 6/3/69	EIR[2] 6/1/68	EIR[2] 7/3/68	EIR[2] 6/3/69
	% Correct			% Correct		
Pussytoes	70	47	88	60	53	88
Trailing Fleabane	72	48	36	58	45	0
Fringed Sagebrush	42	16	20	34	16	27
Total Forbs	61	38	54	48	38	52
Arizona Fesque	62	59	48	74	59	68
Blue Grama	48	72	68	80	62	72
Mountain Muhly	54	59	40	69	48	55
Total Grasses	54	64	52	74	56	64
Total Plants	58	51	53	62	48	60
Bare Soil	90	72	83	35	50	63
Rodent Mounds	72	66	88	90	58	88
Rodent Holes	92	92	100	84	62	88

[1] Anscochrome D-200 (Type 7230)

[2] Ektachrome Infrared Aero (Type 8443)

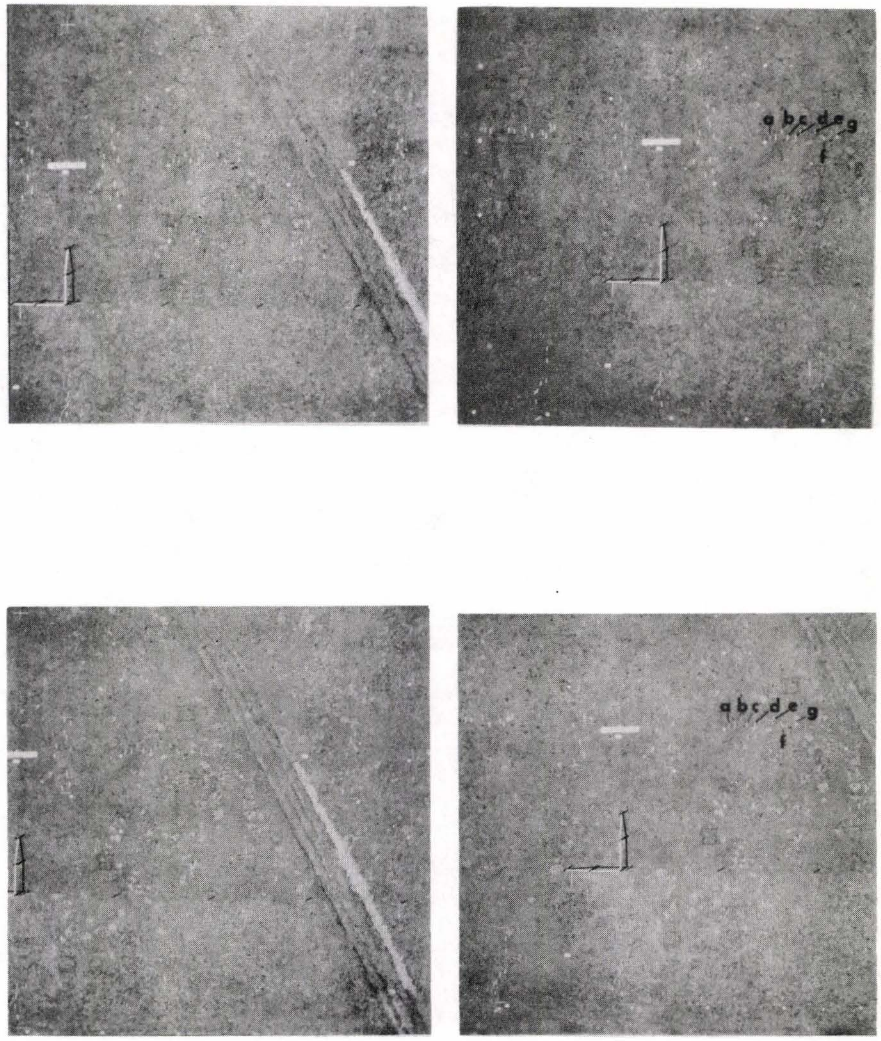


Figure 8 Color (top) and color infrared (bottom), 1:600 stereo pairs of herbaceous species and soil surface features at the Manitou test site. Targets indicated and on ground diameters are: (a) pussytoes - 4 inches, (b) blue gramma - 12 inches, (c) fringed sagebrush - 4 inches, (d) rodent mound - 10 inches, (e) rodent hole - 2 inches, (f) Arizona fescue - 2 inches and (g) mountain muhly - 5 inches. These stereo pairs form a part of the photointerpretation key, Appendix III.

highest percent correct identifications for both plant species and soil surface features (Figure 9). Confidence ratings were also higher for the June flight dates.

Considering all plant species, color infrared photographs provided the highest correct identifications at the June flight dates (Figure 10). Surface features were more easily identified using regular color photographs (Figure 11). It was also found that color infrared was the easier film type to interpret and generally had the highest confidence ratings.

Highest percent correct identification resulted from using the largest scale photographs (1:600 - 1:800). Smaller scales ranging from 1:800 - 1:1000 gave the poorest results. Item detection was greatly reduced resulting in more commission or omission errors at the smaller photoscales. Plant species under two inches in diameter were detectable on the largest scale photos, but could not be identified with acceptable accuracy. Two-inch diameter items were not detectable on the smaller scale photos.

Most plants were more distinct using June photos, but some were more easily identified later in the growing season when size provided discriminate differences. Good examples included Arizona fescue (Festuca arizonica), fringed sagebrush (Artemisia frigida), and trailing fleabane (Erigeron flagellaris). Annual plants and other less abundant species which had appeared in the scene at later flight dates interfered with the identification of the primary species.

Trailing fleabane was difficult to separate from bare soil or old rodent mounds on the late season aerial photos. The species is low growing and had a color signature similar to nonvegetated soil.

Mountain muhly (Muhlenbergia montana) and blue grama (Bouteloua gracilis) were not as easily discriminated on the color photos as on the color IR photos. However, descriptive characters of these species have been redefined and both film types will be reexamined to determine if these species can in fact be

Figure 9 % Correct identification ... all test items

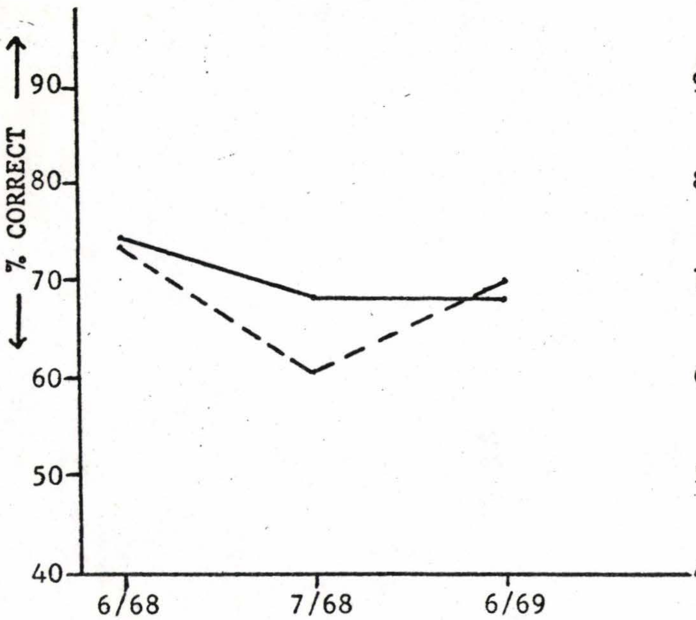


Figure 10 % Correct identification ... all test plants

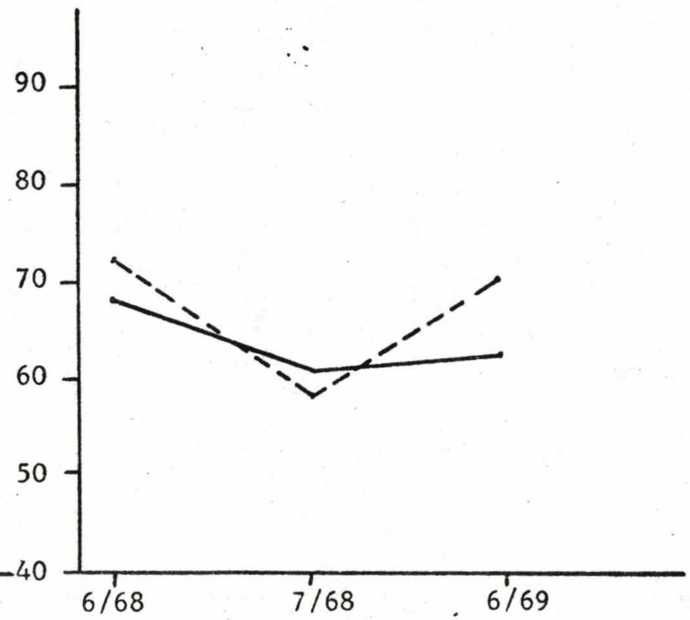
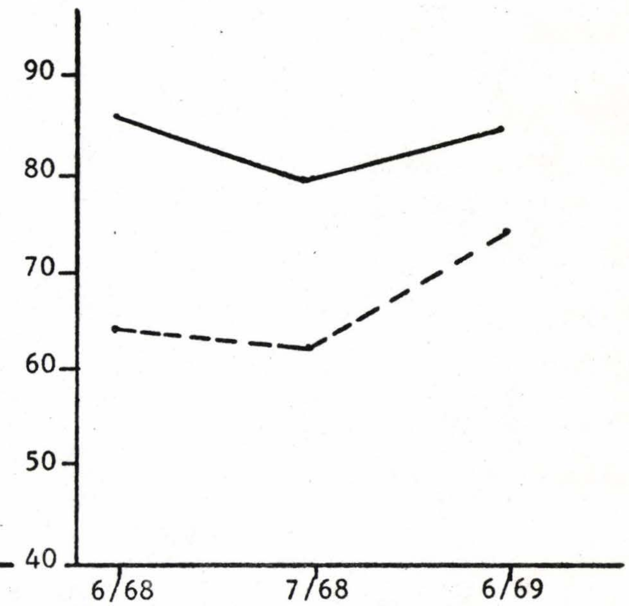


Figure 11 % Correct identification ... surface factors



FLIGHT DATE

——— Anscochrome D-200 (Type 7230)

- - - - - Ektachrome Infrared Aero (Type 8443)

more positively identified. Large diameter fringed sagebrush and Arizona fescue (5 inches or more) can be separated. However, smaller diameter plants (5 inches or less) of these two species were easily confused due to the compact growth form and similar color signatures on both film types.

Photographs from late season missions resulted in frequent commission errors. We plan to revise our descriptive keys to provide for possible increased discrimination among the species under test. These photo interpretation tests will be given to other image analysts with varying degrees of interpretation experience and knowledge of the herbaceous vegetation at Manitou. This will provide further evaluation not only of the film types and flight dates, but of needed modifications in the descriptive keys. Specific questions that need yet to be answered include: (1) What is the scale threshold for acceptable identification of the herbaceous species? (2) What is the effect of associated vegetation on identification of an individual species? (3) What are the effects of cultural treatments including fertilization, herbicidal plant control, and grazing season and intensity on species identification. (4) Which plant species or ground surface characteristics are most often confused with each other and how can they be separated?

Results from this part of our work indicate that large scale color infrared aerial photographs secured in June might be the better film type of the two used to secure the greatest amount of information about herbaceous species identification in areas similar to Manitou. Interpretation of aerial photographs secured at later dates was complicated by confounding effects created by phenological changes. Refinement in image analyses should resolve these confounding effects and provide better results from late season flights, at least for some species. Further research is needed to determine whether statistical differences exist among film types, scales, and dates at the Manitou test site.

Automatic photo interpretation and data processing techniques are being investigated using a scanning microdensitometer and an isodensitracer to identify objects imaged in the aerial transparencies. The isodensitracer automatically scans and measures the optical density of many points in a film transparency, depending on machine aperture size, and plots the measured values as a quantitative two-dimensional isodensity trace.

A 1:2,400 scale 70mm color infrared aerial transparency in which cultural and grazing treatments could be identified was selected to determine the feasibility of using the isodensitracer to discriminate between cultural treatments at the Manitou test site. Results were encouraging since some patterning among treatments was apparent. However, additional research is needed to determine the effects of aperture size and filters for sensing treatment differences before further evaluation can be made. It might be possible that this machine could be used for:

1. Species differentiation based on their optical density.
2. Area delineations by community types.
3. Foliar cover.
4. Utilization or herbage production estimates.

It must be concluded, at this point, that there is no optimum single phenological date of photography for herbaceous species identification in areas similar to the Manitou location. Unlike shrubs, phenological variances of herbaceous species seem to be more important for determining a photo mission time. The total herbaceous component of a community is continually changing throughout the growing season. Therefore, the decision to use large scale aerial photography for herbaceous species identification and subsequent measurement depends strongly on when during the growing season the species of concern flushes in relation to associated species. We have not yet entirely optimized this time element. It is also apparent that complete automation is improbable; that ground truth is an integrated part of total remote sensing application.

C. REMOTE MEASURES OF HERBACEOUS STANDING CROP

Statistical analyses are not yet entirely completed relating photo image density differences to different levels of herbaceous standing crop in big bluegrass pastures. However, some significant differences among various levels using the data we have thus far generated are apparent.

The data were analyzed to compare image density differences among levels of standing crop for each replication and each photoscale. There were significant differences (P = .05) between the 0, 20, and 40 percent and the 80 and 100 percent levels among all replication. In all but one case, the 0 percent treatment was significantly different (P = .05) than all others and the 80 percent treatment was significantly different (P = .05) from the 100 percent treatment.

Treatment/replicate interactions occurred at the mid-range treatments. This could be due primarily to two things: (1) the way the treatments were affected, using height increments of harvesting rather than herbage weight increments. Linearity between height and weight does not exist for herbaceous species, especially grasses; the height-weight relationships are exponentially related. Consequently, image density differences, which are related to mass on the ground, among treatments may not be expected to differentiate as equal class increments. (2) The manner in which we picked data off the strip charts and analyzed it might also be a reason for these interactions. This involved a systematic procedure not necessarily taking advantage of the frequency and amplitude variations of the scan-line readouts. The analyses also did not consider these variations.

Detailed examination of the aerial photographs do indicate differences among levels of standing crop (Figure 12). The scan-line readouts are now being digitized by an Auto-Trol digitizer. This equipment will provide more than four times the number of data points to use for statistical analyses. Since we are dealing with nonrandom population patterns in this problem, these data, with some

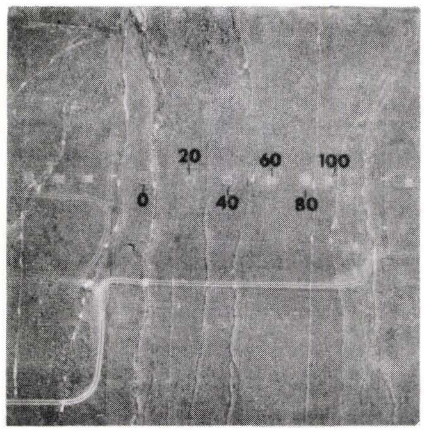


Figure 12 Visual comparison in a color infrared photograph of various levels of herbaceous standing crop in a big bluegrass pasture indicate differences among levels of standing crop. This was verified by microdensitometry which also produced inferences of differences not apparent by visual examination. The numbers represent percent plant height removed.

measures of frequency distribution and amplitude of the scan lines, should provide us with more reliable information for inferences regarding a method for remotely measuring herbaceous standing crop.

MULTISPECTRAL IMAGERY

The NASA RB57F flew over the Manitou test site on July 21 along one flight line approximately 20 miles long. Imagery requested included aerial photographs from nine camera systems and the RS7 imager (Table 5). The mission was accomplished at 11:15 a.m. local sun time at an altitude of approximately 52,000 feet above average terrain height.

On July 28-29, the Michigan optical-mechanical scanner was flown over four flight lines at Manitou. Imagery requested included data from 14 channels in addition to aerial photography from three different aerial camera systems (Table 6). Four diurnal time periods were selected: 0830, 1000, 1200, 1600 local sun time. Imagery was taken from two altitudes: 1,000 and 3,000 feet above mean terrain elevation. A total of 33 flight runs were conducted during the two days.

Detailed mapping of plant communities was completed prior to the flights. During a two week time period bracketing mission coverage, species abundance was determined for each community type. Also, foliar cover for each type was estimated by sampling with 3 x 3 foot sample plots (Figure 13). This plot size represented the resolution element to be "seen" by the optical-mechanical scanners at the lowest flight altitude (1,000 feet). Plots nine-feet square were used at each sampling location to provide data directly related to the scanner resolution element at the 3,000 foot level.

Near vertical ground photos were taken from a stepladder within a representative area of the plant community types using color film (35mm Kodacolor-X) and color infrared (70mm and 35mm Ektachrome Infrared, Type 8443). See Figure 13.

Table 5 Remote sensors requested; NASA RB-57F

Sensor	Film	Film Size	Filter	Lens
RC-8	SO-397	9.5 inch	2E	6 inch
RC-8	2443	9.5 inch	W15	6 inch
Zeiss	2443	9.5 inch	W15	12 inch
Hasselblad	SO-168	70 mm	2E	40 mm
Hasselblad	SO-117	70 mm	W15	40 mm
Hasselblad	SO-117	70 mm	W15/cc30B	40 mm
Hasselblad	2402	70 mm	25	40 mm
Hasselblad	2402	70 mm	58	40 mm
Hasselblad	2424	70 mm	89B	40 mm
RS-7 Imager				

Table 6. Requested spectral bands and aerial photography from the University of Michigan C-47

Scanner System #1 Wavelength (μ)	Scanner System #2 Wavelength (μ)	Cameras
0.52-0.55	0.4-1.0	K-17 with Super 2 film: K-2 Star
0.55-0.58	1.0-1.4	
0.58-0.62	1.5-1.8	KB-8 with 8443 film: W15/cc30B
0.66-0.72	2.0-2.6	
0.80-1.00		KB-8 with 8443 film: W15/cc50B
1.1-1.4		
1.0-2.6		
1.0-5.5		
2.0-2.6		
4.5-5.5		
8.2-13.5		

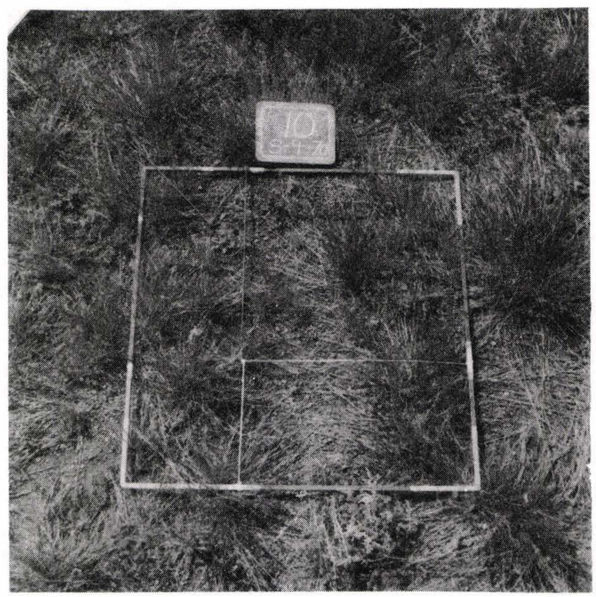


Figure 13 Plots measuring 3 feet on a side were used to estimate foliar cover and species composition of plant communities at the Manitou test site. This plot size represents the resolution element registered multispectrally at the 1,000 foot flight altitude and will be used to identify computer training samples for analyses. Simultaneously, plots 9 feet square were used to provide data directly related to the resolution element at the 3,000 foot flight altitude.

A photo plot was used which represented the 3 x 3 foot cover plot. A general view photo was also taken to show variation within the type. These photos will be used in conjunction with the aerial photos from the C-47 and quantitative ground data for the selection and definition of training samples for processing the scanner imagery.

Immediately prior to and during each scanner overflight, radiometric data was obtained using a Barnes PRT-5 radiometer (Figure 14). These data were relayed to the aircraft by the Forest Service airnet radio system for instrumentation calibration. Data from some representative targets at various times are shown in Table 7.

Two 20 x 40 foot reflectance panels were arranged perpendicular to one of the flight lines. These panels represented reflectance values of 8 and 32 percent and will be used for calibration for processing the data tapes. In addition, a thermal resolution target array was arranged on the ground. These were specially built targets to represent a near perfect absorber and reflector in the 8-14 micrometer wavelength band.

Results cannot yet be reported concerning data from either of these missions since it has not yet been received. However, information received from the mission managers (P. G. Hasell, Michigan and R. Blilie, NASA) immediately after the flights indicate that the data are of good quality.

SUMMARY

For two years, we have concentrated our efforts on three major problem areas. These include: (1) An evaluation of Apollo 9 color infrared frame number 3806 with the objective to develop a multiple sampling technique using various scale aircraft photographs to quantify range resources. (2) An investigation of film, scale and time of photography tests for identification and

Figure 14 A Barnes PRT-5 radiometer was used to collect data on the apparent emitted temperatures of various target scenes included in the scan path of the multispectral imager. The head of the instrument (left) was held a distance from the scene to record the integrated apparent emitted temperature of the total scene and not individual components. In this case, the temperature recorded includes ponderosa pine foliage in direct sunlight and shade.

Table 7. Radiometric data obtained for University of Michigan C-47 flights at Manitou Experimental Forest

	PRT-5 (°C)	MDST	DATE
Rock in full sun	5.5	7:37 a.m.	7-28-70
	24.0	10:50 a.m.	7-28-70
	35.0	2:50 p.m.	7-28-70
	14.0	8:45 a.m.	7-29-70
Standing Open Water	12.0	7:52 a.m.	7-28-70
	12.5	10:50 a.m.	7-28-70
	10.0	2:45 p.m.	7-28-70
	12.0	8:40 a.m.	7-29-70
Shallow Running Water	----	----	7-28-70
	15.5	10:55 a.m.	7-28-70
	22.5	2:55 p.m.	7-28-70
	14.0	8:45 a.m.	7-29-70
Gravelly Soil ... wet in shade	6.0	7:05 a.m.	7-28-70
... wet in sun	8.0	7:05 a.m.	7-28-70
... dry in sun	13.0	7:53 a.m.	7-28-70
... damp in sun	28.0	11:15 a.m.	7-28-70
... dry in sun	31.0	2:45 p.m.	7-28-70
... wet in shade	9.0	8:50 a.m.	7-29-70
... damp in sun	14.5	8:50 a.m.	7-29-70
Ponderosa pine foliage in sun	13.0	7:56 a.m.	7-28-70
	----		7-28-70
	23.0	2:50 p.m.	7-28-70
	19.0	8:50 a.m.	7-29-70
Ponderosa pine litter in sun	21.0	7:54 a.m.	7-28-70
	----		7-28-70
	57.0	2:45 p.m.	7-28-70
	43.0	8:50 a.m.	7-29-70
Willow in sun	14.0	7:56 a.m.	7-28-70
	----		7-28-70
	22.0	2:45 p.m.	7-28-70
	15.0	8:40 a.m.	7-29-70
Meadow Vegetation (partially emerged)	11.0	7:38 a.m.	7-28-70
	19.0	10:55 a.m.	7-28-70

	14.5	8:40 a.m.	7-29-70
Sparse Native Vegetation (Grassland)	14.0	7:41 a.m.	7-28-70

	36.0	2:45 p.m.	7-28-70
	22.0	8:50 a.m.	7-29-70

Table 7 (continued)

	PRT-5 (^{o}C)	MDST	DATE
Dense smooth bromegrass and litter	14.0	7:54 a.m.	7-28-70
	18.0	10:50 a.m.	7-28-70
	33.0	2:45 p.m.	7-28-70
	17.0	8:40 a.m.	7-29-70
Exposed soil on SE facing erosion gully.. dry	23.5	7:58 a.m.	7-28-70
.. wet	16.5	7:58 a.m.	7-28-70
..	----	----	
.. dry	34.0	2:50 p.m.	7-28-70
.. wet	34.0	8:50 a.m.	7-29-70
Resolution targets ... silver	-12.0	7:25 a.m.	7-28-70
... black (smooth)	12.0	7:25 a.m.	7-28-70
... black (rough)	12.5	7:25 a.m.	7-28-70
... silver	-17.0	1:00 p.m.	7-28-70
... black	34.0	1:00 p.m.	7-28-70

Flight Times (Approximately - MST): 7-28-70, 0700
7-28-70, 1100
7-28-70, 1500
7-29-70, 0900

quantification on non-forest (shrubby and herbaceous) vegetation. (3) Remote measures of standing crop of herbaceous vegetation.

A. MULTIPLE SAMPLING WITH SPACE PHOTOGRAPHS

1. The combined effects of original photoscale and ground resolution limits the use of photography from space for inventory, and analyses of range resources. With few exceptions the photo image element used to define a mapping unit will consist of two or more plant community types technically classified by ground examination. This is especially true in areas of frequent changes in soil and topographic situations. In areas where the terrain is relatively constant and vegetation maintains constancy, a single mapping unit defined for space photographs is more likely to represent a single, relatively homogeneous plant community type.

2. Aircraft photographs at various scales are required to sample space photographs for data on the areal extent and composition of the plant community types represented in a single space photo mapping unit. From our work in the Roswell, New Mexico area, photoscales of at least 1:20,000 are required to quantify plant communities verified by on-the-ground examination. Depending on inventory objectives, 1:80,000 scale photographs are useful for separating generalized plant community types. For example, a pinyon-juniper forest area similar to the one used in this experiment can be separated from grasslands or shrublands on 1:80,000 scale photos. The 1:20,000 scale photos were required to interpret community types within the forest, however.

3. Based on our evaluation of five different dot-grid densities at three different intensities of sampling to determine the area of different community types, we found that a grid system of 36 dots per $inch^2$ provided the "best" estimate of area. This was based on using 50 percent of the subsampling units within a primary sampling unit. The "best" estimate is defined as that

grid system which yields an area estimate with the least standard deviation consistent with a minimum cost in relation to sampling intensity.

4. From our New Mexico data, it is apparent that at least a 2:1 ratio of secondary to primary sampling units is required to provide acceptable information about plant community area using 1:20,000 scale photographs. This ratio varies among community types and would have to be determined when working in other area. A similar relationship would be true using 1:80,000 scale photographs provided more than three plant community types could be verified at this photoscale. This latter inference is based on the fact that if only two elements of estimate are involved, in this case plant community area, the extent of one is fixed in relation to the other. Therefore, the calculated variance is the same for both areas.

B. SPECIES IDENTIFICATION

1. Identification of shrubs is significantly more accurate using large scale (1:600 - 1:1,500) color infrared aerial photographs as compared to normal color. This is true regardless of interpreter experience or shrub species. In general, 82 percent of 456 test speciemns were correctly identified on color infrared; 76 percent were corrently identified on normal color.

2. Identification of some shrubs is significantly greater regardless of film type. This is due primarily to shrub size and species diversity in the area imaged on film. Mature plants of tall species growing quite monospecifically are readily identified at photoscales of 1:1,500 and in some cases at photoscales up to 1:2,400. Larger photoscales (1:800 or less) are required for identifying relatively low-growing shrubs in mixed stands.

3. Some shrubs can be identified equally well throughout the growing season. Species such as sagebrush, mountain mahogany, and shrubby cinquefoil maintain sufficient differences, primarily color, from other vegetation throughout the growing season that identification of them on film is equally accurate

regardless of season of photography.

4. Some species such as snowberry and rabbitbrush are difficult to identify regardless of film type, season of photography or photoscale. Image characters and character states are so subtle that acceptable identification is marginal.

5. For our area, early July photographs provided the best information for shrub identification considering all species. We advise detailed phenological observations before a time period for aerial photography for shrub identification is selected for other areas.

6. Aerial photographs in June at scales of 1:600 to 1:800 provide the greatest amount of information for herbaceous species identification in areas similar to our Manitou test site. Most of the plants we used for this test were more distinct on photos secured at this time and scale although some were more easily identified later in the growing season due to increased plant size.

7. In general, color infrared photos provided the highest correct identification for herbaceous plant species. Surface features, such as rodent holes, rodent mounds and bare soil were more easily identified using normal color photographs. This is true regardless of season of photography. We need to refine our descriptions of film image characters and character states for herbaceous species before specific recommendations can be made regarding the best film type or season of photography for identifying these kinds of plants. We are sure the photoscales greater than 1:1,000 have limited usefulness for this purpose.

8. We have had limited success on species identification by microdensitometry. Preliminary results are encouraging on use of an isodensitracer to discriminate among cultural treatments effecting grassland vegetation at the Manitou test site.

C. REMOTE MEASURES OF HERBACEOUS STANDING CROP

1. Broad classes of standing crop of herbaceous vegetation significantly correlated to photoimage density measured by a GAF microdensitometer programmed to scan with an effective circular aperture of $416u^2$ using a green filter.

2. Various treatments were affected on seeded big bluegrass pastures to represent six classes of standing crop, based on crop year growth, ranging from 0 to 100 percent. The reciprocal represents herbage removal and/or herbage utilization. In all but one case, the image density of the 0 percent treatment, representing 100 percent of the current crop year, was significantly different from all others. The image density of the 80 percent treatment, representing 20 percent of the current year growth, was significantly different than the 100 percent treatment, representing 0 production.

3. Treatment interactions occurred among the mid-range classes. This could be due to the way we generated digital data from the strip charts. We are currently working on a program to take advantage of frequency distribution and amplitudes of the scan lines. This should provide us with better digital data to provide more discrete separations of the standing crop classes.

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APPENDIX I

The following is a list of Forest Service, U. S. Department of Agriculture, personnel who contributed to this study and represent a major salary contribution to it:

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APPENDIX II: Dichotomous Keys

Descriptions and Keys - Shrubs

APPENDIX IIa

1. Size: relative as to large for the trees or tall shrubs, or not large which included all other items.
2. Shadow: distinct or not distinct.
3. Crown margin: described as
   a. smooth - no distinct irregularity in the margin.
   b. wavy - minor indentations in the margin.
   c. irregular - deep pockets in the crown margin.
   d. broken - a discontinuous margin but all parts obviously members of the same plant.
4. Crown shape: refers to the relative definition of the crown or the ability to detect in the imagery a definite crown.

   Character states were:
   a. indistinct - no definite crown detectable.
   b. round - detectable with a generally circular shape.
   c. oblong - detectable but not generally circular in shape.
5. Foliage pattern: refers to the appearance of foliage within the crown area of the plant.
   a. continuous - no openings in the crown; appears as a solid mass.
   b. clumpy - openings within the crown give the appearance of small but related masses within the perimeter of the crown.
   c. irregular - appears as single, somewhat detached clumps of foliage; may appear similar to the broken margin character state described under crown margin.

6. Texture: the apparent "graininess" or continuity of pattern of the crown image caused by leaf size, shape, arrangement, and density within the plant. Stated as:

   a. fine
   b. medium
   c. coarse
   d. stippled
   e. mottled
   f. hazy

7. Color: designated numerically and as a descriptive adjective according to National Bureau of Standards ISCC-NBS system of color designations.

APPENDIX IIb

PHOTOINTERPRETATION KEY -- COLOR INFRARED

1. Plants large (small trees or large shrubs)

    2. Foliage slightly purplish pink (247) to dark purplish pink (251); shadow distinct, crown margin usually irregular to broken; crown shape round or oblong; foliage pattern very clumpy; medium texture . . . . *Juniperus scopulorum*

    2. Foliage red or shade of red

        3. Foliage medium reddish brown (43); shadow distinct; crown margin smooth to wavy; crown shape round; foliage pattern very clumpy; coarse to mottled texture . . . . *Pinus edulis*

        3. Foliage very red (11) or deep red (13); crown margin wavy to broken; crown shape round or indistinct; fine texture; foliage pattern irregular (numerous single branches) . . . *Cercocarpus montanus*

1. Plants not as large (small or medium shrubs)

    4. Foliage reddish purple or purplish pink

        5. Reddish purple

            6. Low growing; light reddish purple (240) may almost be reddish brown in some plants; usually spreading (large diameter for height); shadow not distinct; crown margin smooth to wavy; crown shape usually round; fine texture. . *Artemisia longiloba*

            6. Not low growing; pale reddish purple (244) to light reddish purple (240); shadow distinct; crown margin broken, crown shape variable; foliage pattern clumpy medium texture . . . . *Artemisia tridentata*

        5. Slightly purplish pink (247) to dark purplish pink (251); shadow distinct; crown margin usually smooth to wavy; crown shape round or oblong; foliage pattern either in clumps or continuous; texture medium . . . . *Juniperus scopulorum*

    4. Foliage not reddish purple or purplish pink

        7. Foliage pattern in clumps

8. Shadow distinct

9. Foliage medium reddish brown (43); crown margin smooth to wavy; crown shape round; texture coarse . . . Pinus edulis

9. Foliage not reddish brown

10. Texture coarse; light gray purplish red (261) or dark red (16); crown margin usually irregular (may be smooth in young plants); crown shape round or indistinct. . . . . Potentilla fruticosa

10. Texture fine; slightly pink (2) to deep pink (3) or dark red (16); crown margin usually smooth but variable; crown shape usually round or oblong but not conical . . . . Chrysothamnus parryi

8. Shadow not distinct

11. Texture coarse or hazy; usually medium red (15) or slightly red (12) occasionally dark red (16) or deep red (13); crown margin smooth to wavy; crown shape variable . . . . Purshia tridentata

11. Texture not coarse or hazy

12. Dark red (16) or deep red (13) (sometimes has slight pinkish or magenta cast to plant); crown margin smooth to wavy; crown shape usually more irregular than Purshia tridentata . . . . Symphoricarpos spp.

12. Very dark red (17) or very deep red (14) (a maroon); usually smaller than Symphoricarpos spp. and larger than Gutierrezia sarothrae; may be a spreading and very low-growing plant; crown margin irregular; crown shape usually oblong or indistinct; texture fine; color may be very similar to Gutierrezia sarothrae

Chrysothamnus viscidiflorus

7. Foliage pattern continuous

13. Dark reddish brown (44) or deep reddish brown (41); shadow not distinct; usually very low-growing plant with small diameter and not spreading; crown margin smooth; crown shape round or oblong; texture fine . . . . . Gutierrezia sarothrae

13. Not reddish brown

14. Slightly pink (2) to deep pink (3) or dark red (16) shadow distinct; crown margin smooth; crown shape round or oblong; texture fine to medium . . . Chrysothamnus parryi

14. Not pink

15. Shadow very distinct; very bright red (11) or sometimes dark red (16); crown margin wavy to broken; crown shape round or indistinct (numerous single branches); texture fine . . . . Cercocarpus montanus

15. Shadow not distinct

16. Foliage red

17. Medium red (15) or slightly red (12); crown margin wavy; crown shape round; texture fine . . . . . Purshia tridentata

17. Very dark red (17) or very deep red (14); crown margin smooth to wavy; crown shape round or oblong; texture fine . . . . Chrysothamnus viscidiflorus

16. Foliage slightly purplish (255) red to medium purplish red (258); crown margin smooth; crown shape round or oblong; texture fine . . . . Symphoricarpos spp.

APPENDIX IIc

PHOTOINTERPRETATION KEY -- COLOR

1. Plants large (small trees or large shrubs)

   2. Foliage light gray olive (109); crown margin wavy to broken; crown shape irregular; foliage pattern clumpy; texture fine; shadow distinct . . . . <u>Juniperus scopulorum</u>

   2. Foliage dark green

      3. Foliage pattern irregular (numerous single branches); crown margin wavy to broken; crown shape round or indistinct; texture fine; dark gray green (151) or dark green (146) . . . <u>Cercocarpus montanus</u>

      3. Foliage pattern clumpy (no single branches); shadow distinct; crown margin smooth to wavy; crown shape usually round; texture coarse; dark gray green (151) . . . . <u>Pinus edulis</u>

1. Plants not as large

   4. Low growing

      5. Foliage pattern usually clumpy; shadow not distinct; crown margin wavy to irregular; crown shape variable; texture medium; very dark green (147) gray olive green (127) or dark olive green (126) . . . . <u>Chrysothamnus viscidiflorus</u>

      5. Foliage pattern more continuous

         6. Spreading (usually large diameter for height); crown margin smooth to wavy; crown shape usually round; texture fine or grainy; gray olive (110) . . . . <u>Artemisia longiloba</u>

         6. Not a spreading plant; usually small round plant; shadow not distinct; crown margin smooth or wavy; crown shape round or oblong; texture fine; foliage blackish green (152) . . . . <u>Gutierrezia sarothrae</u>

   4. Not as low growing

      7. Shadow distinct

         8. Foliage light olive gray (112) or light gray olive (109)

9. Foliage light olive gray (112); crown margin broken; crown shape variable; foliage pattern clumpy; texture medium . . . . <u>Artemisia tridentata</u>

9. Foliage light gray olive (109); crown margin wavy to broken; crown shape irregular; foliage pattern clumpy; texture fine . . . .<u>Juniperus scopulorum</u>

8. Foliage dark gray green (151); dark green (146), or very dark green (147)

10. Foliage pattern irregular (numerous single branches); crown margin wavy to broken; crown shape round or indistinct; foliage fine textured; dark gray green (151) or dark green (146). . . . . <u>Cercocarpus montanus</u>

10. Foliage pattern continuous or clumpy

11. Texture coarse; crown margin smooth to wavy; crown shape usually round; foliage pattern clumpy; foliage dark gray green (151). . . . . <u>Pinus edulis</u>

11. Texture not coarse

12. Texture fine; crown margin variable; crown shape variable; foliage pattern continuous to clumpy; crown margin usually round or oblong but not conical; usually lighter green than <u>Potentilla fruticosa</u>; foliage dark green (146) . . . . <u>Chrysothamnus parryi</u>

12. Texture medium; usually larger than <u>Chrysothamnus parryi</u>; crown margin variable; crown shape variable; foliage pattern continuous to clumpy; foliage very dark green (147) . . . . <u>Potentilla fruticosa</u>

7. Shadow not distinct

13. Texture hazy or coarse; crown margin smooth to wavy; crown shape variable but usually round or irregular; foliage pattern continuous to slightly clumpy; foliage medium olive green (125) or dark olive green (126). . . <u>Purshia tridentata</u>

13. Texture not hazy

14. Foliage very dark green (147), gray olive green (127) or dark olive green; plant small; crown margin wavy to irregular; crown shape variable; foliage pattern slightly clumpy to very clumpy; texture medium coarse . . . . Chrysothamnus viscidiflorus

14. Foliage gray green (150) or dark green (146); crown margin variable; crown shape variable; foliage pattern slightly clumpy; texture fine. . . . . Symphoricarpos spp.

APPENDIX III: Descriptive Keys

Herbaceous Species

APPENDIX IIIa

COLOR INFRARED (8443)

Muhlenbergia montana: may be nondistinct and appear as a typical Bouteloua gracilis or small, dense, oblong Festuca arizonica; usually an irregular shaped patch; may also be irregular-circular to oblong-dense clumpy; uneven density with mildly rough to rough texture; larger plants may have faint shadows created by seed stalks especially in fertilized treatments...

Herbicide treatment: usually light to medium reddish purple (240-241)[1] or medium purplish pink (250); when nondistinct deep to medium purplish (256-258)

Fertilizer treatment: usually light gray purplish red (261-262) to slightly purplish red (255); when nondistinct pale purplish blue (203), light purplish pink (249), or gray reddish purple (245)

Fertilizer/Herbicide treatment: usually medium to gray purplish red (258-262) or dark purplish pink (251); when nondistinct (262) (see Figure 8)

Native: usually pale to light purple (222-227) or slightly purplish red (255); when nondistinct pale to light purplish pink (242-249) or very pale purple (226)

Bouteloua gracilis: generally an irregular shaped patch, may be oblong-circular, low usually with uneven density; smooth to somewhat rough textured; seed stalks add to overall rough texture of larger plants especially in fertilized treatments...

Herbicide treatment: grayish purple (228) to light, pale, or gray reddish purple (240, 244, 245); when nondistinct purplish pink (262)

Fertilizer treatment: slightly to very purplish red (254-255), pale reddish purple (244), or light reddish purple (240); nondistinct medium purplish red (258)

Fertilizer/Herbicide treatment: medium purplish red (258), slightly purplish red (255), light purplish pink (249), to pale gray purple (227-226) (see Figure 8)

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[1] Numbers in parentheses refer to National Bureau of Standards ISCC-NBS system of color designation (Centroid Color Chips).

Native: very pale to very light purple (226-221), light purplish gray (232), dark purple pink (257), or medium purplish red (258)

Antennaria spp.: generally an irregular shaped mat, evenly dense with smooth texture; may be somewhat rough textured with uneven density; usually very distinct...

Herbicide treatment: light to medium purplish pink (249-250) or light purplish gray (232)

Fertilizer treatment: slightly purplish pink (247), or light to deep purplish pink (250-251)

Fertilizer/Herbicide treatment: slight, medium, to light purplish pink (247, 248, 249) (See Figure 8)

Native: slightly to light purplish pink (249-247), or medium purplish red (258)

Festuca arizonica: generally a circular shaped clump; very dense with even density; texture varies from mildly rough to rough depending upon presense or absense of seed stalks; if seed stalks are present they are usually a light straw color; plant is generally accompanied by a distinct shadow if relatively large; grazed or smaller plants may have a faint shadow; small plants appear as a red spot; may be nondistinct when smaller and/or with a dead center...

Herbicide treatment: medium, deep, or very dark purplish red (258, 256, 260) to slightly reddish purple (237)

Fertilizer treatment: gray purplish pink, deep reddish purple (238) to very deep red (11-13)

Fertilizer/herbicide treatment: deep, dark to very dark red (13, 16, 17), or deep purplish red (256) (See Figure 8)

Native: grayish to deep purple.

Artemisia frigida: generally (if large enough) appears as an irregular to circular shaped plant; usually bushy with rough texture; may be low with no shadow, or when large with height (bushy) shadow is distinct...

Herbicide treatment: usually absent or nondistinct, may appear as small reddish spot

Fertilizer treatment: medium to very purplish red (258-254), or reddish pink to grayish pink

Fertilizer/herbicide treatment: deep purplish pink (248) to medium purplish red (258), or slightly to very purplish red (255-254) (See Figure 8)

APPENDIX IIIb

COLOR (D-200)

Muhlenbergia montana: usually a distinct irregular shaped patch, but may be somewhat circular to oblong; smooth to uneven rough texture; may have very faint height (or relief) with no shadow...

Herbicide treatment: usually dark gray green (151)[2]; may be gray green (150) to gray yellowish green (122)

Fertilizer treatment: usually dark gray green (151) to medium olive green (125); may occasionally be yellow gray (93) to gray yellow (90)

Fertilizer/herbicide treatment: usually dark gray green (151); may be gray green (150) to light greenish gray (154) (See Figure 8)

Native: usually dark gray green (151); may be medium to dark olive green (125-126)

Bouteloüa gracilis: usually a distinct irregular shaped patch, but may be somewhat circular; smooth to uneven rough texture; may be somewhat "bushy" in fertilizer treatment but with no shadow...

Herbicide treatment: usually gray green (150) to pale green (149); may be gray olive green (127) to yellowish gray (93)

Fertilizer treatment: usually gray green (150) to pale green (149); may be gray yellow green (122), dark yellow green (137), or light gray olive (109)

Fertilizer/herbicide treatment: usually gray green (150) to pale green (149); may be light greenish gray (154) to greensih gray (155) (See Figure 8)

Native: usually gray green (150) to pale green (149)

Antennaria spp.: usually distinct irregular shaped mat; smooth to unevenly smooth texture; dense; no shadow or height...

Herbicide treatment: usually light greenish gray (154); may be yellowish white (92) to light gray white (263-264)

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2 Numbers in parentheses refer to National Bureau of Standards ISCC-NBS system of color designation (Centroid Color Chips)

Fertilizer treatment: light greenish gray (154); may be yellow gray (93) to pale yellow green (121)

Fertilizer/herbicide treatment: light greenish gray (154); to pale yellowish green (12) (See Figure 8)

Native: light greenish gray (154)

<u>Festuca arizonica</u>: generally a dense circular shaped clump; distinct with or without dense seed stalk stubble (straw colored); may have shadow and height, usually if shadow is present it is very distinct; nondistinct if dead centered...

Herbicide treatment: dark green (146) to very dark green (147)

Fertilizer treatment: dark green (146) to dark olive green (126)

Fertilizer/herbicide treatment: dark green (146) to very dark green (147) (See Figure 8)

Native: very dark green (147)

<u>Artemisia frigida</u>: generally nondistinct; but when distinct, may be somewhat circular and rounded in shape; larger plants are "bushy" with height and shadow; uneven to rough texture...

Herbicide treatment: dark gray green (151) to dark green gray (156)

Fertilizer treatment: gray green (150) to gray yellowish green (122); may be medium yellow green (136)

Fertilizer/herbicide treatment: medium olive green (125) to dark green (146) and dark gray green (151) (See Figure 8)

Native: dark gray green (151)